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# *Analysis of Flood Discharge due to Land Used Changes in Keramasan Watershed Palembang, Indonesia*

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*Abstract*— **Changes in land use in the catchment area have a significant impact on flood discharge. This phenomenon also occurs in the Keramasan watershed. This study aims to determine the impact of land use changes on flood discharge. To calculate the flood discharge used the rational method. The data used in this study include rainfall data, land use data and topographic data. Rainfall data used is daily rainfall data recorded at BMKG Kenten Palembang. Daily rainfall is transformed into hourly rainfall intensity using the Mononobe method.**

**The results of this study indicate that the increase in flood discharge due to changes in land use is approximated by the linear trend equation $Y = a + b*X_1 + c*X_2 + d*X_3$. Variable Y is flood discharge. The variables $X_1$, $X_2$, and $X_3$ are the area of rice fields, the area of agricultural land, and the area of housing. The combination correlation coefficient is 0.96. Variables a, b, c, and d are –350.60, 33.63, -75.00, and 1.006. The partial correlation coefficient, $RYX_1$ is 0.57, $RYX_2 = 0.57$, and $RYX_3 = 0.57$.**

**Keywords—land uses changes, flood discharge, multi regression**

## I. INTRODUCTION

The Keramasan river has a watershed area of about 8,233 km2, with a river length of about 313 km, which flows from the south to the upper reaches of the river around Baturaja and empties into the Musi river in the Kertapati district of Palembang, better known as Muara Ogan. Changes in land use in watersheds (DAS) have a dominant influence on flood discharge (Jayadi 2000). Changes in land use in conservation areas to built areas can clearly cause floods, landslides and droughts. Floods are streams/puddles of water that cause economic losses or can even cause loss of life (Asdak 1995). This flow / puddle can occur due to overflows in the area to the right or left of the river due to the river channel not having sufficient capacity for the flow of the passing stream (Sudjarwadi 1987). This happens because during the rainy season, not much rainwater that falls on the catchment area can seep into the ground, but rather overflows as river water discharge. If the river discharge is too large and exceeds the river's cross-sectional capacity, it will cause flooding.

Increased flood discharge can also have an impact on the failure of flood control buildings (dams, weirs, embankments, drainage channels, etc.). This is because the flood control building is not able to withstand the force load due to the flood discharge which has increased due to changes in land use. Based on the above considerations, it is necessary to pay attention to the impact caused by changes in land use in the Keramasan watershed.

## II. Research Methods

### *A.* Frequency Analysis

The formula used to calculate the statistical parameters of rainfall is as follows.

Average value ( $\overline{R}_1$ )

$$\overline{R}i = \frac{1}{n}\sum_{i=1}^{n} Ri \qquad (1)$$

Standar devation (Sd)

$$S = \left| \frac{\sum \left(R_1 - \overline{R}_1\right)^2}{(n-1)} \right|^{1/2} \qquad (2)$$

Coefficient skewness (Cs)

$$C_S = \frac{n\sum_{i=1}\left(R_i - \overline{R}_i\right)^4}{(n-1)(n-2)S^3} \qquad (3)$$

Sharpness coefficient (Ck)

$$C_K = \frac{n^2\sum_{i-1}\left(R_i - \overline{R}_i\right)^4}{(n-1)(n-2)(n-3)Sd^4} \qquad (4)$$

Coefficient of Variation (Cv)

$$C_V = \frac{Sd}{\overline{R}_i} \qquad (5)$$

with :

n = Number of data / length of data

R = Rainfall (mm)

$\overline{R_1}$ = Average rainfall (mm)

Sd = standard deviation / standard deviation

*B.* **Rainfall Intensity Analysis**

Rainfall intensity has a relationship between the duration of the rain and the frequency of rain which is usually given in the form of a curve called the IDF (Intensity Duration Frequency) curve. From this curve, it can be seen the amount of rain intensity with return periods of 5, 10, 25, 50 and 100 years. The following is the calculation of the rainfall intensity for the 5 year return period.

TABLE I. NUMBER PARAMETER GUMBEL DISTRIBUTION MAXIMUM RAINFALL

| Return Period (Years) | $R_{24}$(mm) |
|---|---|
| 5 | 125.984 |
| 10 | 145.140 |
| 25 | 169.341 |
| 50 | 187.294 |
| 100 | 205.118 |

$$I = \left(\frac{R_{24}}{24}\right)\left(\frac{24}{t}\right)^{\frac{2}{3}}$$

$$= \left(\frac{125{,}984}{24}\right)\left(\frac{24}{0{,}3247}\right)^{\frac{2}{3}}$$

= 257.1460 mm/jam

Intensity calculations for 5, 10, 25, 50 and 100 year return periods in a 10-minute time span can be seen in Table II. below this:

TABLE II. RAIN INTENSITY WITH RETURN PERIOD AND RAIN DURATION

| t | | Return Period | | | | |
|---|---|---|---|---|---|---|
| Minute | Hours | 5 | 10 | 25 | 50 | 100 |
| 5 | 0.083 | 228.928 | 263.736 | 307.713 | 340.337 | 372.724 |
| 10 | 0.167 | 144.216 | 166.143 | 193.847 | 214.399 | 234.801 |
| 20 | 0.333 | 90.850 | 104.664 | 122.116 | 135.063 | 147.916 |
| 30 | 0.500 | 69.332 | 79.873 | 93.192 | 103.072 | 112.881 |
| 40 | 0.667 | 57.232 | 65.934 | 76.928 | 85.084 | 93.181 |
| 50 | 0.833 | 49.321 | 56.820 | 66.295 | 73.323 | 80.301 |
| 60 | 1.000 | 43.676 | 50.317 | 58.707 | 64.931 | 71.110 |
| 70 | 1.167 | 39.411 | 45.403 | 52.974 | 58.590 | 64.166 |
| 80 | 1.333 | 36.054 | 41.536 | 48.462 | 53.600 | 58.700 |
| 90 | 1.500 | 33.331 | 38.399 | 44.802 | 49.552 | 54.267 |
| 100 | 1.667 | 31.070 | 35.795 | 41.763 | 46.191 | 50.586 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 110 | 1.833 | 29.158 | 33.591 | 39.192 | 43.347 | 47.472 |
| 120 | 2.000 | 27.514 | 31.698 | 36.983 | 40.904 | 44.797 |
| 130 | 2.167 | 26.085 | 30.051 | 35.061 | 38.779 | 42.469 |
| 140 | 2.333 | 24.827 | 28.602 | 33.371 | 36.909 | 40.422 |
| 150 | 2.500 | 23.711 | 27.316 | 31.871 | 35.250 | 38.605 |
| 160 | 2.667 | 22.713 | 26.166 | 30.529 | 33.766 | 36.979 |
| 170 | 2.833 | 21.813 | 25.130 | 29.320 | 32.428 | 35.514 |
| 180 | 3.000 | 20.997 | 24.190 | 28.223 | 31.216 | 34.186 |
| 190 | 3.167 | 20.254 | 23.334 | 27.224 | 30.111 | 32.976 |
| 200 | 3.333 | 19.573 | 22.549 | 26.309 | 29.098 | 31.867 |
| 210 | 3.500 | 18.947 | 21.827 | 25.467 | 28.167 | 30.848 |
| 220 | 3.667 | 18.368 | 21.161 | 24.689 | 27.307 | 29.906 |
| 230 | 3.833 | 17.832 | 20.543 | 23.968 | 26.510 | 29.032 |
| 240 | 4.000 | 17.333 | 19.968 | 23.298 | 25.768 | 28.220 |
| 250 | 4.167 | 16.868 | 19.432 | 22.672 | 25.076 | 27.463 |
| 260 | 4.333 | 16.432 | 18.931 | 22.087 | 24.429 | 26.754 |
| 270 | 4.500 | 16.024 | 18.460 | 21.539 | 23.822 | 26.089 |
| 280 | 4.667 | 15.640 | 18.018 | 21.023 | 23.251 | 25.464 |
| 290 | 4.833 | 15.278 | 17.602 | 20.537 | 22.714 | 24.875 |
| 300 | 5.000 | 14.937 | 17.208 | 20.078 | 22.206 | 24.319 |
| 310 | 5.167 | 14.614 | 16.836 | 19.643 | 21.726 | 23.794 |
| 320 | 5.333 | 14.308 | 16.484 | 19.232 | 21.271 | 23.295 |
| 330 | 5.500 | 14.017 | 16.149 | 18.842 | 20.839 | 22.822 |
| 340 | 5.667 | 13.741 | 15.831 | 18.470 | 20.428 | 22.373 |
| 350 | 5.833 | 13.478 | 15.528 | 18.117 | 20.037 | 21.944 |
| 360 | 6.000 | 13.227 | 15.239 | 17.780 | 19.665 | 21.536 |

From the results of the calculation of the intensity of rain for each return period in a span of 10 minutes. So that IDF curves can be made. The following is the shape of the IDF curve from the rain intensity data that has been obtained which is shown in Figure 1.

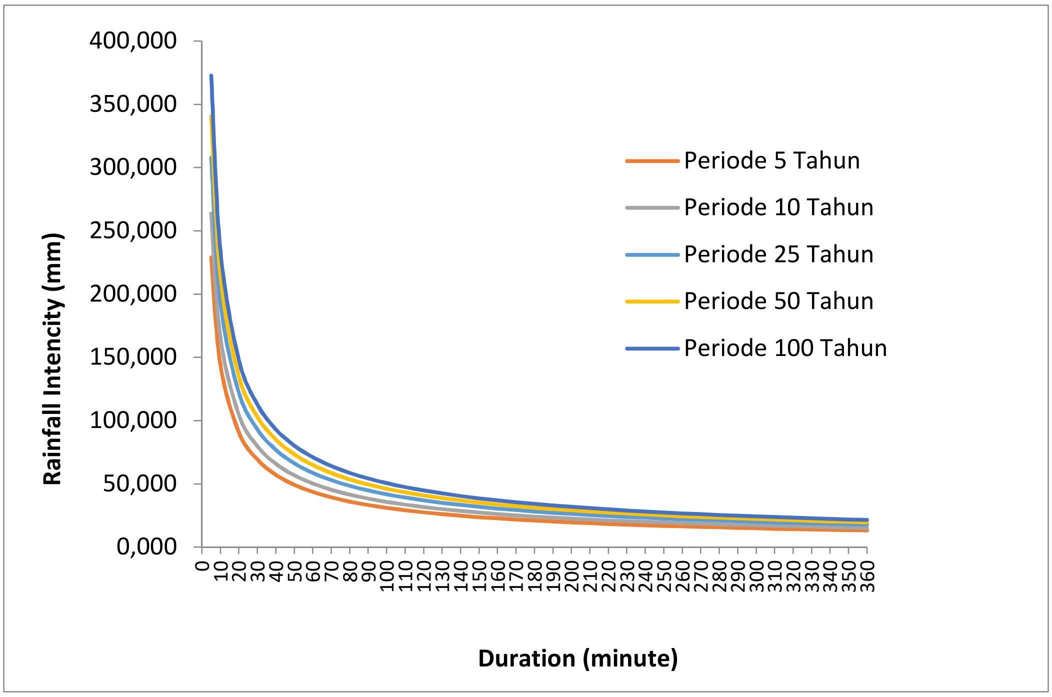


Fig. 1. Intensity Duration Frequency Curve

### *C.* Hyetograph Rain Design Alternate Block Method (ABM)

The distribution of rain as a function of time that describes each variation in the depth of rain during the rain, which can be expressed in the form of a Hyetograph (Histogram). In this study, the design Hyetograph will use ABM (Alternative Block Method), which is a simple way to create a design Hyetograph from the IDF curve.

The calculation of the design rain hytograph using ABM (Alternati Block Method) for a 5 year return period can be seen in Table 2. and the graph obtained from the calculation results shown in Figure 2.

An explanation of the ABM (Alternati Block Method) calculation table for a 5 year return period, namely the duration of rain (column 1) is determined to be 360 minutes.

Column 4 is the multiplication between rain intensity (column 3) and duration.

Column 5 is the hourly rain depth whose value is obtained from the successive difference in the depth of rain (column 4).

Column 6 contains the hourly rainfall depth value which is represented by means of each row in column 5 (hourly rain depth) divided by the number and then multiplied by one hundred.

Column 7 is the Hyetograph expressed in percent.

Column 8 is the Hyetograph in millimeters (mm) which is obtained by multiplying column 7 (percent of the Hyetograph) with the annual return period design rainfall value divided by one hundred.

TABLE III. CALCULATION OF ALTERNATIVE BLOCK METHOD WITH 5 YEARS RETURN PERIOD

| Rainfall Duration | | Rainfall Intencity | Duration x Intencity | Rainfall depth | | Hyetograph | |
|---|---|---|---|---|---|---|---|
| menit | jam | mm/jam | mm | mm | % | % | mm |
| 10 | 0.167 | 144.216 | 24.036 | 24.036 | 30.285 | 0.935 | 1.17749 |
| 20 | 0.333 | 90.850 | 30.283 | 6.247 | 7.872 | 0.971 | 1.223906 |
| 30 | 0.500 | 69.332 | 34.666 | 4.382 | 5.522 | 1.012 | 1.275185 |
| 40 | 0.667 | 57.232 | 38.155 | 3.489 | 4.396 | 1.057 | 1.332197 |
| 50 | 0.833 | 49.321 | 41.101 | 2.946 | 3.712 | 1.108 | 1.396041 |
| 60 | 1.000 | 43.676 | 43.676 | 2.575 | 3.245 | 1.165 | 1.468129 |
| 70 | 1.167 | 39.411 | 45.979 | 2.303 | 2.902 | 1.231 | 1.550308 |
| 80 | 1.333 | 36.054 | 48.072 | 2.093 | 2.637 | 1.306 | 1.645046 |
| 90 | 1.500 | 33.331 | 49.997 | 1.925 | 2.425 | 1.394 | 1.755725 |
| 100 | 1.667 | 31.070 | 51.784 | 1.787 | 2.252 | 1.498 | 1.887124 |
| 110 | 1.833 | 29.158 | 53.455 | 1.672 | 2.106 | 1.624 | 2.046237 |
| 120 | 2.000 | 27.514 | 55.029 | 1.573 | 1.982 | 1.781 | 2.243785 |
| 130 | 2.167 | 26.085 | 56.517 | 1.488 | 1.875 | 1.982 | 2.497163 |
| 140 | 2.333 | 24.827 | 57.930 | 1.413 | 1.781 | 2.252 | 2.836835 |
| 150 | 2.500 | 23.711 | 59.278 | 1.348 | 1.698 | 2.637 | 3.322084 |
| 160 | 2.667 | 22.713 | 60.567 | 1.289 | 1.624 | 3.245 | 4.088071 |
| 170 | 2.833 | 21.813 | 61.803 | 1.236 | 1.558 | 4.396 | 5.53821 |
| 180 | 3.000 | 20.997 | 62.992 | 1.189 | 1.498 | 7.872 | 9.917208 |
| 190 | 3.167 | 20.254 | 64.138 | 1.146 | 1.443 | 30.285 | 38.15469 |
| 200 | 3.333 | 19.573 | 65.244 | 1.106 | 1.394 | 5.522 | 6.956689 |
| 210 | 3.500 | 18.947 | 66.313 | 1.070 | 1.348 | 3.712 | 4.676808 |
| 220 | 3.667 | 18.368 | 67.350 | 1.036 | 1.306 | 2.902 | 3.655624 |
| 230 | 3.833 | 17.832 | 68.355 | 1.005 | 1.267 | 2.425 | 3.055574 |
| 240 | 4.000 | 17.333 | 69.332 | 0.977 | 1.231 | 2.106 | 2.653484 |
| 250 | 4.167 | 16.868 | 70.282 | 0.950 | 1.197 | 1.875 | 2.362012 |
| 260 | 4.333 | 16.432 | 71.206 | 0.925 | 1.165 | 1.698 | 2.139326 |
| 270 | 4.500 | 16.024 | 72.108 | 0.901 | 1.136 | 1.558 | 1.962658 |
| 280 | 4.667 | 15.640 | 72.987 | 0.879 | 1.108 | 1.443 | 1.818462 |
| 290 | 4.833 | 15.278 | 73.846 | 0.859 | 1.082 | 1.348 | 1.698134 |
| 300 | 5.000 | 14.937 | 74.685 | 0.839 | 1.057 | 1.267 | 1.595921 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 310 | 5.167 | 14.614 | 75.506 | 0.821 | 1.034 | 1.197 | 1.50782 |
| 320 | 5.333 | 14.308 | 76.309 | 0.803 | 1.012 | 1.136 | 1.430951 |
| 330 | 5.500 | 14.017 | 77.096 | 0.787 | 0.991 | 1.082 | 1.363185 |
| 340 | 5.667 | 13.741 | 77.867 | 0.771 | 0.971 | 1.034 | 1.302912 |
| 350 | 5.833 | 13.478 | 78.623 | 0.756 | 0.953 | 0.991 | 1.248888 |
| 360 | 6.000 | 13.227 | 79.365 | 0.742 | 0.935 | 0.953 | 1.200137 |
| | | | | 79.365 | 100 | | 125.984 |

Then, with the above calculation results, the next step is to create an ABM (Alternative Block Method) Hyetograph. The following is shown in Figure 2.

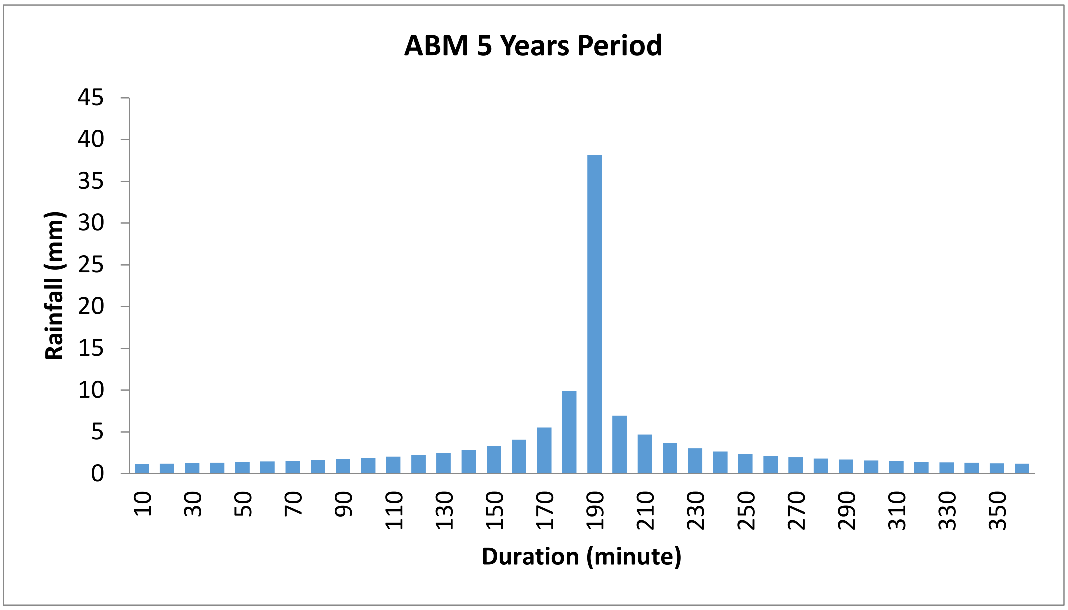


Fig. 2. Hyetograph with ABM Method 5 Years Return Period

## III. Results and Discussion

### A. Flood Discharge

Based on the hydrological analysis in the previous chapter, the planned flood discharge can be calculated based on the Gumbel method. The flood discharge in question can be seen in the following table for each specific return period

TABLE IV. FLOOD DISCHARGE

| No. | $R_{24}$ (mm) | Intencity (I) (mm/jam) | Q ($m^3$/det) |
|---|---|---|---|
| 1 | 125,984 | 257,1460 | 35.47 |
| 2 | 145,140 | 296,2446 | 40,87 |
| 3 | 169,341 | 345,6414 | 47,69 |
| 4 | 187,294 | 382,2866 | 52,74 |
| 5 | 205,118 | 418,6661 | 57,76 |

**B. Runoff Analysis**

The runoff coefficient reflects the surface state of the flow area. The flow coefficient, C is the ratio of the volume of water that reaches the mouth of the watershed with the volume of water that falls above the watershed.

The value for the coefficient of drainage, C. Data obtained from Bappeda Palembang City, the area of land use for residential areas are:

High density area = 7.09 km2

The area of the catchment area = 7.37 km2

Trade area area = 4.73 km2

Based on table 4.27 the flow coefficient for residential areas with high density area is taken 0.90 and for the catchment area is taken 0.40 and for the trade area is taken 0.90. Then the value of Cw:

$$C_w = \frac{A_1C_1 + A_2C_2 + A_nC_n}{A_1 + A_2 + A_n}$$

$$C_w = \frac{(7.09 \times 0.9) + (7.37 \times 0.4) + (4.73 \times 0.9)}{7.09 + 7.37 + 4.73} = 0.708$$

The value of the runoff coefficient is obtained, Cw = 0.708 and in the calculation is taken Cw = 0.70.

Table 4. Flow coefficient C

TABLE V. COEFFICIENT C

| Zona | Land Used | C |
|---|---|---|
| Urban | Residential Area: | |
| | - Low density | 0,25-0,40 |
| | - Medium density | 0,40-0,70 |
| | - High density | 0,70-0,80 |
| | - with infiltration well | 0,20-0,30 |

| | | |
|---|---|---|
| | Trade Area | 0,90-0,95 |
| | Industrial area | 0,80-0,90 |
| | Parks, green lines, gardens, etc | 0,20-0,30 |
| Rural | Hills, slope<20% | 0,40-0,60 |
| | Gorge area, slope>20% | 0,50-0,60 |
| | Land with terraces | 0,25-0,35 |
| | rice fields | 0,45-0,55 |

To calculate the surface runoff discharge by using the Rational formula. The runoff coefficient (C) is determined from land use.

### C. Flow Capacity (Discharge)

To calculate the flow capacity (discharge) surface (Run Off) using the Rational Formula. It is known that the runoff coefficient (C) = 0.70, with a watershed area of 25.95 km2 then:

$$Q = 0.2778.C.I.A$$
$$= 0.2778 \times 0.70 \times 257.146 \times 25.95$$
$$= 129.76 \text{ m3/s}$$

For return periods of 2, 5, 10, 20 and 50, it can be seen in the following table:

TABLE VI. RUNOFF DISCHARGE CALCULATION RESULTS

| Return Period (Years) | C | I (mm/jam) | A (km$^2$) | Q (m$^3$/det) |
|---|---|---|---|---|
| 2 | 0,70 | 257.1460 | 25,95 | 36,04499 |
| 5 | 0,70 | 296.2446 | 25,95 | 41,52557 |
| 10 | 0,70 | 345.6414 | 25,95 | 48,44968 |
| 20 | 0,70 | 382.2866 | 25,95 | 53,58636 |
| 50 | 0.70 | 418.6661 | 25,95 | 58,68579 |

### D. Analysis of Land Function Changes on Flood Discharge

From the results of multi-regression analysis, the relationship between land use area and flood discharge is as follows:

| Years | Land Used Area ($km^2$) | | | | Flood Discharge ( Y ) |
|---|---|---|---|---|---|
| | Paddy fields ($X_1$) | Dry fields, ($X_2$) | Settlements ($X_3$) | Others ($X_4$) | |
| **2014** | 19,0948 | 7,6414 | 12,8256 | 30,8482 | 48,4496 |
| **2015** | 19,2066 | 7,6414 | 12,8127 | 30,8482 | 49,6365 |
| **2016** | 20,1282 | 7,9073 | 11,5263 | 30,8482 | 49,3889 |
| **2017** | 20,3284 | 7,6578 | 11,5756 | 30,8482 | 50,5528 |
| **2018** | 20,6822 | 7,8112 | 11,0686 | 30,8482 | 56,2529 |
| **2019** | 20,8012 | 7,7014 | 11,0592 | 30,8482 | 61,8408 |
| **2020** | 20,8287 | 7,6933 | 11,0398 | 30,8482 | 67,3679 |

Then a simple statistical analysis with a certain return period is obtained as follows:

| Y | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_1^2$ | $X_2^2$ | $X_3^2$ | $X_4^2$ |
|---|---|---|---|---|---|---|---|---|
| **Discharge** | **Paddy Fields** | **Dry Fields** | **Settlements** | **Others** | | | | |
| 48.44 | 12.83 | 7.64 | 19.09 | 30.85 | 164.6089 | 58.3696 | 364.4281 | 951.7225 |
| 49.63 | 12.81 | 7.64 | 19.21 | 30.85 | 164.0961 | 58.3696 | 369.0241 | 951.7225 |
| 49.38 | 11.53 | 7.91 | 20.13 | 30.85 | 132.9409 | 62.5681 | 405.2169 | 951.7225 |
| 50.55 | 11.58 | 7.66 | 20.33 | 30.85 | 134.0964 | 58.6756 | 413.3089 | 951.7225 |
| 56.25 | 11.07 | 7.81 | 20.68 | 30.85 | 122.5449 | 60.9961 | 427.6624 | 951.7225 |
| 61.84 | 11.06 | 7.7 | 20.8 | 30.85 | 122.3236 | 59.29 | 432.64 | 951.7225 |
| 67.36 | 11.04 | 7.69 | 20.83 | 30.85 | 121.8816 | 59.1361 | 433.8889 | 951.7225 |
| **383.4894** | **81.92** | **54.05** | **141.07** | **215.95** | **962.4924** | **417.4051** | **2846.1693** | **6662.0575** |

| $Y^2$ | $YX_1$ | $YX_2$ | $YX_3$ | $YX_4$ |
|---|---|---|---|---|
| | | | | |
| 2,346.43 | 621.4852 | 370.0816 | 924.7196 | 1494.374 |
| 2,463.14 | 635.7603 | 379.1732 | 953.3923 | 1531.0855 |
| 2,438.38 | 569.3514 | 390.5958 | 994.0194 | 1523.373 |
| 2,555.30 | 585.369 | 387.213 | 1027.6815 | 1559.4675 |
| 3,164.06 | 622.6875 | 439.3125 | 1163.25 | 1735.3125 |

| | | | | |
|---|---|---|---|---|
| 3,824.19 | 683.9504 | 476.168 | 1286.272 | 1907.764 |
| 4,537.37 | 743.6544 | 517.9984 | 1403.1088 | 2078.056 |
| **21,333.10** | 31415.452 | 20727.602 | 54098.85 | 82814.536 |

**E. Regression Equation**

The form of the regression equation from the results of the analysis is:

Y = βo + β1 $X_1$ + β2 X2 + β3 X3 +β4X4

Y = -350.6 + 33.64X1 - 75X2 + 1.537X3 + 1.006X4

JKreg = 33.64 (81.92) + (-75) (54.05) + 1.537 (141.07) + 1.006 (215.95)

= 20601.744

JKres = JKY - JKreg

JKY = 383.4894– (20601.7442) / 7 = 322.856.28

JKres = 322.856.28 – 20.601.744 = 302254.5

**F. Coefficient of Determination**

R2 = 302254.5 – 322856.28 = 0.936

**G. Total Correlation Coefficient:**

Ryx1 = R2 = 0.969

**H. Error Coefficient**

Re2 = 1 – R2 = 1 – 0.936 = 0.064

Re = 0.25

**I. Partial Correlation Coefficient**

Ry1 = 81.92 / (962.4924) (21.333.10) = 0.57

Ry2 = 54.05 / (417.4051) (21.333.10) = 0.57

Ry3 = 141.07/ (2846.1693) (21.333.10) = 0.57

**J. Correlation Coefficient Significance Test:**

$F_{Count}$ = 16.17

**K. Test Criteria:**

If $F_{Table} \leq F_{Count}$, then Ho is accepted

If $F_{Table} \geq F_{Count}$, then Ho is rejected

With a significant level = 0.05

F Table = F (1.α ) ( db numerator = m ) (db denominator = n – m -1 )

= F (1.0.05) (4) (7-4-1)

= F(0.95) (4) (2)

$F_{Table}$ = 7.6

It turns out that $F_{Table} \leq F_{Count}$, it can be said that there is a significant effect of land use change on increasing flood discharge in the Keramasan watershed.

## IV. CONCLUSION

1. The flood discharge calculated in this study is 48.45 m3/s with a return period of 10 years.
2. The percentage change due to the land use change is the equation Y = a+bX1+cX2+dX3 where the Y variable is flood discharge, while X1, X2, X3 and X4 are paddy fields, dry fields, settlements with their respective correlation coefficients. -partially are RYX1 = 0.57, RYX2 = 0.57, and RYX3 = 0.57.
3. Combined, the value of the Correlation Coefficient that occurs is 0.97 or 97%, an increase in discharge in the Keramasan watershed is due to the conversion of paddy fields, dry fields, and settlements.

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